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Stennis Space Center, MS 39529-5004

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Digital Mapping, Charting, and Geodesy Analysis Program (DMAP)

Technical Review of Proposed Ice Objects for AML

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14. ABSTRACT

The United Kingdom Hydrographic Office requested a review of proposals received for incorporating ice objects into the Additional Military Layers (AML) product. Two proposals were made by the Canadian Ice Service: (1) No amendments are necessary to ice objects in Maritime Foundation and Facilities (MFF) product specification and (2) High Resolution Environment (HRE) (or Environment, Seabed, and Beach (ESB)) is revised to bring it into line with the ECDIS Ice Objects Version 3.0, but without extending the scope of HRE. It is noted that MFF and HRE (or ESB) both contain Sea Ice-Ice Area and Land Ice-Ice Area. Separate consideration will be given to removing all ice from MFF to ensure that there is no duplication of data (or to confirming that there are different specifications for different purposes).

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Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) Technical Review of Proposed Ice Objects for AML

1.0 Background

The United Kingdom Hydrographic Office requested a review of proposals received for incorporating ice objects in to the Additional Military Layers (AML) product. Two proposals were made by the Canadian Ice Service: 1) No amendments are necessary to ice objects in Maritime Foundation and Facilities (MFF) product specification and 2) High Resolution Environment (HRE) (or Environment, Seabed and Beach (ESB)) is revised to bring it into line with the ECDIS Ice Objects Version 3.0, but without extending the scope of HRE. It is noted that MFF and HRE (or ESB) both contain Sea Ice – Ice Area and Land Ice – Ice Area. Separate consideration will be given to removing all ice from MFF to ensure that there is no duplication of data (or to confirming that there are different specifications for different purposes).[1]

For this review, DMAP specifically focused on Annex A[2] of the referenced document which presented the proposed changes to the AML Product Specification HRE to bring it into line with the ECDIS Ice Objects. The following areas are discussed within this review:

- problems of temporal stability
- lack of codes for icebergs
- World Meteorological Organization Ice Chart Symbology "Egg Code"
- AML ice features as compared to DIGEST, SEDRIS, and IHO S-57.

A review of the DIGEST FACC indicated insufficient features and attributes to encode sea ice information. It is the opinion of DMAP that neither the AML objects nor Digital Geographic Information Exchange Standard (DIGEST) are sufficient to handle the required information. We recommend that at a minimum, the features and attributes should permit the encoding of the essential information contained in the World Meteorological Organization (WMO) "Egg Code" (see http://www.natice.noaa.gov/sigrid.htm and http://www.natice.noaa.gov/egg.htm for complete specifications). This is discussed in detail in Section 3.

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[1] United Kingdom Hydrographic Office, HA324/006/030/01, dtd 20 June 2001, *Update Following Ad Hoc Hydrographic Working group 24-25 April2001. AML Product Specifications.*

[2] Ibid.

Manuscript approved August 10, 2001.

2.0 Noted Omissions

The inclusion of sea ice and iceberg information with navigation chart information is beneficial, but not without the problem of how to handle perishable data, i.e., information that is valid only for a short time span.

2.1 Temporal Stability

Charts historically have displayed information that was, in general, temporally stable within the frequency of the chart update/publish cycle. Sea ice is highly variable in both its spatial and temporal aspects. The addition of sea ice to charts/navigation display can be highly effective, but the information must be current and accurate. Looking at "outdated" ice information could lead to problems when operating in ice prone regions. In many situations, no information is better than false (or outdated) information. With "no ice" information, but ice a possibility, appropriate watch and operational procedures would be implemented. However, with "ice" indicated on the navigational display, a course would be steered to avoid the ice and no extra precautions taken. But the ice could have moved and the displayed information is no longer current, causing the vessel to operate in a less than prudent manner.

With this in mind it is essential that ice or temporally variable information be handled and attributed appropriately, possibly with the attributes for time of 1) issue, 2) forecast validity, and 3) expiration. It is recommended that discussion be conducted and consideration be given to developing standards and procedures for perishable data when used in conjunction with electronic chart displays.

2.2 Icebergs

DIGEST does not contain feature or attribute codes that specify icebergs. Consideration of attributes and values might prove useful. The following list is offered[3]:

BJ ***Hydrography – Snow/Ice***
BJ050 Iceberg

And when needed as a value rather than a feature:

Ice Classification
ICC *10* *Iceberg*

Potential attributes that might be associated with *BJ050 Iceberg* are:

NAM Name of iceberg
LEN Length (approximate m)

[3] Italics denote possible values for inclusion in DIGEST.

WID Width (approximate m)
DTE Expiration date of information
ELA Elevation accuracy
EXS Existence category
HGT Height above surface (approximate m)
HDP Depth below surface (approximate m)
HYC Hydrological category
LOC Location category
xxx *Date/time last position fix*
xxx *Estimate direction of movement (ref. true north)*
xxx *Estimate speed of movement (knots)*

3.0 World Meteorological Organization

3.1 Ice Chart Symbology – Egg Code

As mentioned previously, it is suggested that the information content of the "egg code" would be a good starting point for the identification of sea ice attributes. Toward this end we have included an explanation of the "egg code" as given by NOAA. Further information can be obtained through their website: http://www.natice.noaa.gov.

The World Meteorology Organization (WMO) system for sea ice symbology is more frequently referred to as the "Egg Code" due to the oval shape of the symbol.[4] As shown in Fig. 1, the Egg is made up of four identifiers: Total Concentration, Partial Concentrations, Stage of Development, and Floe Size.

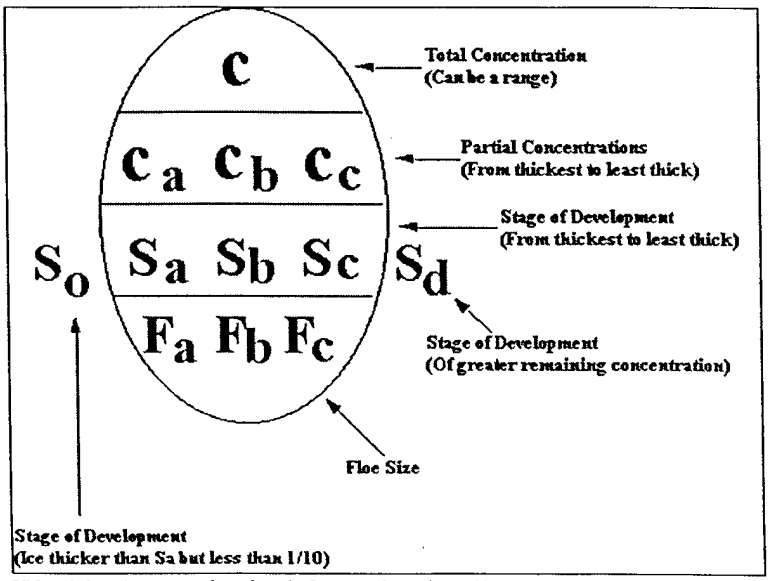

Fig. 1. World Meteorological Organization "Egg Code" for Sea Ice Symbology

[4] World Meteorological Organization website, http://www.natice.noaa.gov/egg.htm

The following is an example of "egg codes" in use from http://www.natice.noaa.gov/pub/special_report/forecast/East/2001/w30daye010401gif.

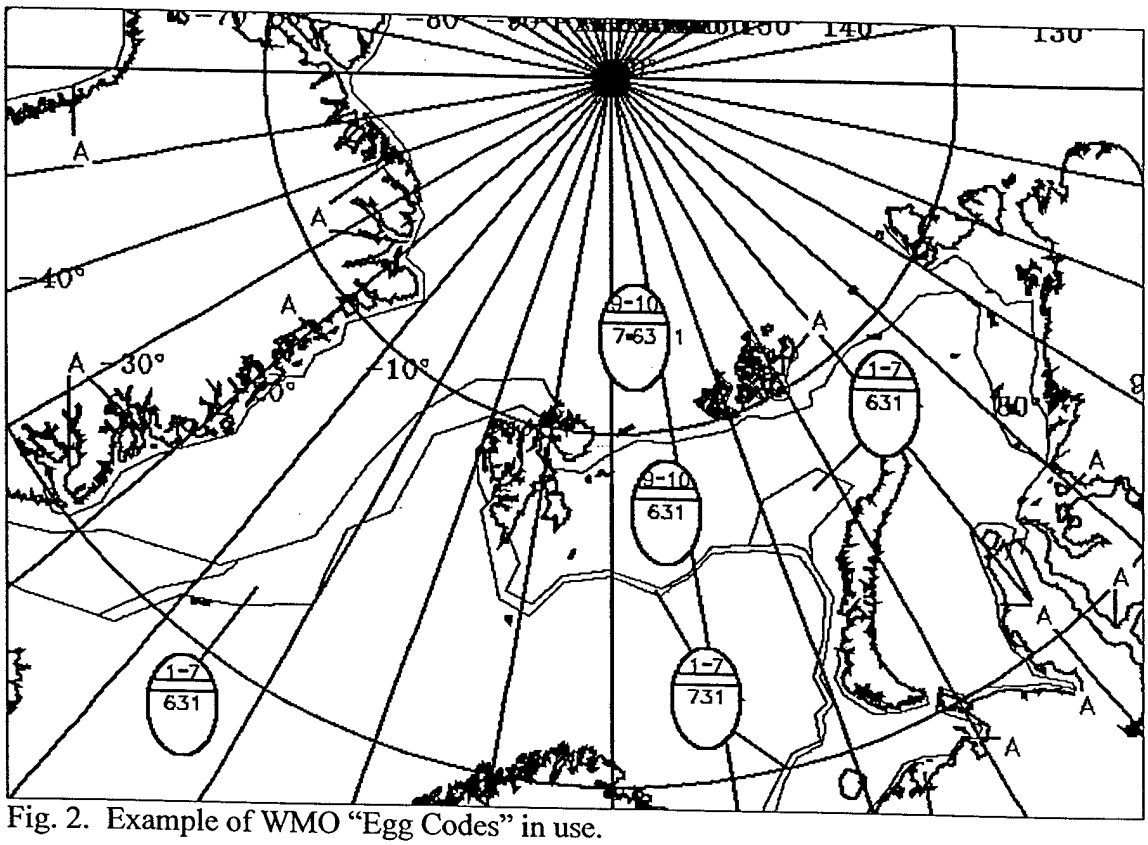

Fig. 2. Example of WMO "Egg Codes" in use.

Each of these identifiers is then defined further by specific codes to identify concentration and stages of development. The following tables give examples of the associated definitions and attributes for Concentration, Stages of Development and Forms of Sea Ice.

The detail of the code values can become confusing if not familiar, as can be seen from the following tables. To start with an explanation, **C** represents concentration, **S** equals Stage of Development, and **F** is Forms of Ice. The **a, b, c** are first, second and third values; **p** is predominant, **s** is secondary. However, rather than paying attention to the schema to arrive at the value headings, concentrate on the definitions as these would represent values for attribute features in DIGEST (see Section 4 for examples of possible DIGEST feature and attribute codes).

Table 1. Sea Ice Concentration Symbols

Sea Ice Concentration Symbols		Variable(s)
CT	Total concentration, CC (Code Table 1)	CC
CA	Partial concentration, stage of development and form of thickest ice CaCaSaSaFaFa (Code tables 1, 2, and 3)	CaCaSaSaFaFa
CB	Partial concentration, stage of development and form of second thickest ice CbCbSbSbFbFb (Code tables 1, 2, and 3)	CbCbSbSbFbFb
CC	Partial concentration, stage of development and form of third thickest ice CcCcScScFcFc (Code tables 1, 2, and 3)	CcCcScScFcFc
CF	Predominant FpFp and secondary FsFs form of ice (Code table 3)	FpFpFsFs
CN	Stage of development of ice thicker than reported by SaSa but with a concentration less than 1/10, SoSo (Code table 2)	SoSo
CD	Stage of development of any remaining class of ice not reported under CA, CB, or CC (Code table 2). Note that no concentration or form of ice is reported for SoSo and SdSd.	SdSd

Table 2. Sea Ice Variables

List of Sea Ice Variables	
Variable Code	**Definition**
CC	Total concentration of all ice in the area, reported in tenths (Code Table 1)
CaCaCbCbCcCc	Partial concentration of respectively thickest, second thickest and third thickest ice reported in tenths (Code Table 1)
FaFaFbFbFcFc	Form of ice corresponding to SASa, SbSb, and ScSc respectively (Code Table 3)
FpFpFsFs	Predominant (FpFp) and Secondary (FsFs) form of ice (Code Table 3)
SaSaSbSbScSc	Stage of development of respectively thickest, second thickest and third thickest ice of which the concentration is reported CaCa, CbCb and CcCc respectively (Code Table 2)
SdSd	Stage of development of any remaining class of ice not reported by SaSa, SbSb, ScSc or SoSo (Code Table 2)
SoSo	Stage of development of ice thicker than SaSa but with a concentration less than 1/10 (Code Table 2)

Table 3 shows the code figure values used within the "egg code" and the definitions for each of the Code Tables for Concentration, Stage of Development and Form of Ice.

3.2 Comparison of WMO "Egg Code" and AML Sea Ice

An attempt was made to map the WMO "egg code" into the defined AML features and attributes for Sea Ice and it was found that there were only a few in agreement. We recommend that this be pursued.

4.0 Comparison Review of AML Sea Ice with DIGEST, SEDRIS, and IHO S-57 Standards

Possible DIGEST and FACC Codes for Sea Ice

A review of the tables in Appendices A-D indicate that there is no clear cut comparison for the AML Sea Ice requirements within existing DIGEST, Synthetic Environment Data Representation & Interchange Specification (SEDRIS), or IHO S-57 (Digital Hydrographic Data) codes. It should be noted from these tables that some codes are included, most are not. For this reason, a conversion to the DIGEST Feature and Attribute Code Catalog (FACC) would require a new FACC code for Sea Ice (e.g., *BJ010*[5]), with the following possible structure. Note, an attribute for Sea Ice already exists in DIGEST (i.e., ICC, value 2); however the FACC structure does not allow for additional values specifically related to sea ice. It is therefore recommended that a new FACC code for Sea Ice be developed within DIGEST, using the values and attributes of the "egg code", with the following as a possible structure:

BJ Hydrography – Snow/Ice
BJ010 Sea Ice

Attribute	Definition
CCN	***Concentration*** *(identified and defined in Table 3, Code Table 1)*
ICD	***Stage of Development or Thickness of Ice*** *(identified and defined in Table 3, Code Table 2)*
ICC*	***Form of Ice*** *(identified and defined in Table 3, Code Table 3)*

* ICC already exists as a feature in FACC, the attribute *Form of Ice* does not.

Appendix E is a combined comparison chart for all four documents referencing sea ice.

[5] Proposed additions to DIGEST.

5.0 Conclusions and Recommendations

Neither DIGEST nor the proposed AML features adequately describe ice features when the WMO Egg Code is used as a starting point for the identification of the salient attributes.

Additionally, the combination of "perishable" data with electronic chart display, could result in less than prudent ship navigation if not handled appropriately.

With this in mind, the following recommendations are made:

- Develop standardized methods for the handling and display of perishable data in conjunction with electronic chart display.
- Expand DIGEST Features and Attributes to adequately contain sea ice and iceberg information as specifically mentioned in Section 2.
- Expand the proposed AML codes to accommodate ice features adequately and to deal with the "perishable" data problem.
- Expand the proposed AML codes to reflect World Meteorological Organization "Egg Code" features and attributes.
- Ensure the National/Naval Ice Center has reviewed content requirements with their domain knowledge and naval mission in mind.

6.0 Acknowledgments

The Oceanographer of the Navy (N096) funded this effort to evaluate the Proposed Ice Objects for Additional Military Layers, under the direction of LCDR Karen Ruppe. This evaluation, funded under Program Element 0603704N, is a part of the Naval Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) long-term focus of enhancing the Navy's use and development of digital MC&G technologies. DMAP greatly appreciates the ongoing efforts of Dr. Edward Mozley, SPAWAR Program Manager.

Table 3. Value and Definitions of Concentration, Stage of Development, and Form of Ice

Code Figure	Code Table 1 – Concentration (CC, Ca, Cb, Cc)	Code Table 2 – Thickness of Ice or Stage of Development (Sa, Sd, So)		Code Table 3 – Form of Ice (Fa, Fp)	
Value	Definition	Stage of Development	Thickness	Form	Size Concentration
00	Ice Free	Ice Free		Pancake Ice	30 cm – 3 m
01	Less than 1/10 (open water)			Shuga/Small Ice Cake, Brash Ice	< 2 m across
02	Bergy Water			Ice Cake	< 20 m across
03				Small Floe	20 m – 100 m across
04				Medium Floe	100 m – 500 m across
05				Big Floe	500 m – 2 km across
06				Vast Floe	2 km – 10 km across
07				Giant Floe	> 10 km across
08				Fast Ice	
09				Growlers, Floebergs or Floebits	
10	1/10			Icebergs	
11				Strips and Patches	Concentration: 1/10
12				Strips and Patches	Concentration: 2/10
13				Strips and Patches	Concentration: 3/10
14				Strips and Patches	Concentration: 4/10
15				Strips and Patches	Concentration: 5/10
16				Strips and Patches	Concentration: 6/10
17				Strips and Patches	Concentration: 7/10
18				Strips and Patches	Concentration: 8/10
19				Strips and Patches	Concentration: 9/10
20	2/10			Strips and Patches	Concentration: 10/10
21				Level Ice	
30	3/10				
40	4/10				
50	5/10				
60	6/10				
70	7/10				
80	8/10	No Stage of Development			
81		New Ice			
82		Nilas, Ice Rind	< 10 cm		

Code Figure	Code Table 1 – Concentration (CC, Ca, Cb, Cc)	Code Table 2 – Thickness of Ice or Stage of Development (Sa, Sd, So)		Code Table 3 – Form of Ice (Fa, Fp)	
Value	Definition	Stage of Development	Thickness	Form	Size Concentration
83		Young Ice	10 – 30 cm		
84		Grey Ice	10 – 15 cm		
85		Grey – White Ice	15 – 30 cm		
86		First Year Ice	30 – 200 cm		
87		Thin First Year Ice	30 – 70 cm		
88		Thin First Year Stage 1	30 – 50 cm		
89		Thin First Year Stage 2	50 – 70 cm		
90	9/10	For Later Use			
91	More than 9/10 less than 10/10	Medium First Year Ice	70 – 120 cm		
92	10/10	For Later Use			
93		Thick First Year Ice	> 120 cm		
94		For Later Use			
95		Old Ice			
96		Second Year Ice			
97		Multi-Year Ice			
98		Glacier Ice			
99		Undetermined/Unknown		Undetermined/Unknown	

Appendix A
DIGEST FACC, Part 4, Annex A – Feature Codes[6]

BB – Hydrography – Ports and Harbors

BB202 Ice Boom
Floating barriers, anchored to the bottom, used to deflect the path of floating ice in order to prevent the obstruction of locks, intakes, etc., and to prevent damage to bridge piers and other structures.

BD - Hydrography-Dangers/Hazards

BD000 US-Underwater Danger/Hazard UK-Underwater Danger
A known underwater object or area, known to be dangerous to surface navigation.

BD005 Miscellaneous Underwater Feature
An object or area on the sea floor or underwater that is not identified by any other code in this specification. (Also see BD000)

BD070 Obstruction (Nautical)
A danger to navigation, the exact nature of which is not specified, or has not been determined.

BJ - Hydrography-Snow/Ice

BJ020 Moraine
An accumulation of soil and stone debris deposited by a glacier.

BJ030 Glacier
A large mass of snow and ice moving slowly down a slope or valley from above the snowline.

BJ040 Ice Cliff
The vertical face of a glacier or ice shelf.

BJ060 Ice Peak/Nunatak
A rocky peak projecting above a surrounding ice field that may be perpetually covered with ice.

BJ065 Ice Shelf
A sheet of thick ice, with level or undulating surface, attached to the land but mostly afloat which is bounded on the seaward side by an Ice Cliff (BJ040).

BJ070 Pack Ice
An area of ice formed by the drifting and crushing together of floating pieces of ice.

BJ080 Polar Ice
The heaviest, thickest form of ice over land or water (see also BJ100)

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[6] Digital Geographic Information Working Group, *The Digital Geographic Information Exchange Standard (DIGEST), Part 4 – Annex A, Feature Codes,* Ed. 2.1, September 2000.

BJ100 Snow Field/Ice Field
A large area permanently covered by snow or ice over land or water (see also BJ080)

BJ110 Tundra
A prairie-like region in the Arctic and Subarctic zones which sustains a growth of low vegetation.

Appendix B
DIGEST FACC, Part 4, Annex B – Attribute and Value Codes[7]

ICC Ice Classification
Tabulates the kind of ice.

ICC	0	Undefined
ICC	1	Fast ice
ICC	2	Sea ice
ICC	3	Growler area
ICC	4	Pancake ice
ICC	5	Glacier (See BJ030)
ICC	6	Ice Peak (See BJ060)
ICC	7	Pack ice (See BJ070)
ICC	8	Polar ice (See BJ080)
ICC	9	Debris-covered
ICC	997	Unpopulated
ICC	998	Not Applicable
ICC	999	Other

ICE Ice Factor
The value of the maximum variation in the vertical clearance of an overhead cable due to an accumulation of ice.

ICE	0	Actual Value

MCC Material Composition Category
Characteristics of primary material composition of feature.

MCC	103	Snow/Ice

SIC Snow/Ice Category
Indicates the composition of the feature.

SIC	0	Unknown
SIC	1	Snow
SIC	2	Ice
SIC	997	Unpopulated
SIC	998	Not Applicable
SIC	999	Other

UMC Underlying Material Characteristics
Characteristics of underlying material composition of feature.

UMC	19	Glacial

[7] Digital Geographic Information Working Group, *The Digital Geographic Information Exchange Standard (DIGEST), Part 4 – Annex B, Attribute and Value Codes,* Ed. 2.1, September 2000.

Appendix C
IHO S-57 Appendix A[8]

Category of Ice
Feature Code: CATICE

ID	Meaning	Definition
1	Fast ice	Sea ice which remains fast, generally in the position where originally formed, and which may attain a considerable thickness. It is found along coasts, where it is attached to the shore, or over shoals, where it may be held in position by islands, grounded icebergs or grounded polar ice.
2	Sea ice	Any form of ice which has originated from sea water. Generally any ice in the sea.
3	Growler area	A low-lying mass of flow ice which is not easily seen by approaching vessels owing to its dark indigo colour. It is therefore a menace to shipping. It is usually caused by the capsizing and disintegration of an iceberg.
4	Pancake ice	Pieces of new ice, usually approximately circular, about 30 cm to 3 m across, and with raised rims, due to the pieces striking against each other as the result of wind and swell.
5	Glacier	A mass of snow and ice continuously moving from higher to lower ground or, if afloat, continuously spreading.
6	Ice peak	[no definition provided]
7	Pack ice	Term used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how it is disposed.
8	Polar ice	Sea ice that is more than one year old (in contrast to winter ice). The WMO code defines polar ice as any sea ice more than one year old and more than 3 metres thick.

Remark: Ice is the topic of another group and is subject to a future extension to this document.

[8] International Hydrographic Organization, *IHO Transfer Standard for Digital Hydrographic Data, Ed. 3.0, Special Publication No. 57*, November 1996.

Appendix D
SEDRIS

Hydrography – Dangers/Hazards

BD000	Underwater Danger	A known underwater object or area, known to be dangerous to surface navigation.
BD005	Miscellaneous Underwater Feature	An object or area on the sea floor or underwater that is not identified by any other code in this specification (see also BD000)
BD070	Obstruction (Nautical)	A danger to navigation, the exact nature of which is not specified, or has not been determined.

Hydrography – Snow/ice

BJ020	Moraine	An accumulation of soil and stone debris deposited by a glacier.
BJ030	Glacier	A large mass of show and ice moving slowly down a slope or valley from above the snowline.
BJ040	Ice Cliff	The vertical face of a glacier or ice shelf.
BJ060	Ice Peak/Nunatak	A rocky peak projecting above a surrounding ice field that may be perpetually covered with ice.
BJ065	Ice Shelf	A sheet of thick ice, with level or undulating surface, attached to the land but mostly afloat which is bounded on the seaward side by an ice cliff (BJ040)
BJ066	Ice Keel	An irregular linear downward extension of sea ice formed where two moving areas of ice.
BJ070	Pack Ice	An area of ice formed by the drifting and crushing together of floating pieces of ice.
BJ075	Polynya	A large area of open water surrounded by sea ice.
BJ080	Polar Ice	The heaviest, thickest form of ice over land or water (see also BJ100).
BJ100	Snow Field / Ice Field	A large area permanently covered by snow or ice over land or water (see also BJ080).
BJ110	Tundra	A prairie-like region in the Arctic and Subarctic zones which sustains a growth of low vegetation.

Appendix E
Comparison Chart of AML Ice Objects, DIGEST Attributes and Values, SEDRIS and IHO S-57

ECDIS Ice Object	HRE Comments	AML Object	DIGEST FACC Code (and SEDRIS)	DIGEST Attribute & Value	IHO S-57 CATICE
Sea Ice	Model as ECDIS Ice Objects but with lower level of attribution.	Sea Ice		ICC 2 Sea Ice	Sea Ice
Lake Ice	Suggest that this is not required for AML	--			
Ice Advisory Area	May be worth including in Routes, Areas and Limits	--			
Iceberg Area	Model as ECDIS Ice Objects	Iceberg			
Land Ice	Model as ECDIS Ice Objects	Glacier	BJ030 Glacier	ICC 5 Glacier UMC 19 Glacial	ICEARE Glacier
Ice Line	Not required for AML	--			
Ice Route	Not required for AML	--			
Ice Fracture	Could include but would require further definitions	--			
Ice Polynya	Model as ECDIS Ice Objects	Polynia	BJ075 Polynya (SEDRIS only)		
Ice Lead	Model as ECDIS Ice Objects	Lead			
Iceberg	Include	Iceberg			
Floeberg	Not necessary for AML to differentiate between an iceberg and a floeberg	--			
Ice/Snow Thickness	Not necessary for AML, thickness attributes on sea ice object sufficient	--			
Ice Movement	Not required for AML	--			
Ice Dynamics	Not required for HRE or Maritime Foundation and Facilities	--			
Ice Ridge	Not required for AML	--			
Ice Opening	Could use object Ice Opening instead of ice lead, ice polynya and ice fracture or not include	Lead			
Ice Topography	ICETOP. Not required for AML				
				ICE 0 Ice Factor	
				MCC 103 Snow/Ice	
				SIC 1 Snow	
				SIC 2 Ice	
			BB202 Ice Boom		Ice Boom
			BD000 Underwater Danger/Hazard		OBSTRN
			BD005 Miscellaneous Underwater Feature		

ECDIS Ice Object	HRE Comments	AML Object	DIGEST FACC Code (and SEDRIS)	DIGEST Attribute & Value	IHO S-57 CATICE
			BD070 Obstruction		
			BJ020 Moraine		
			BJ040 Ice Cliff		
			BJ060 Ice Peak/ Nunatak	ICC 6 Ice Peak	HILTOP Ice Peak
			BJ065 Ice Shelf		ICEARE Ice Shelf
			BJ066 Ice Keel (SEDRIS only)		
			BJ070 Pack Ice	ICC 7 Pack Ice	Pack Ice
			BJ080 Polar Ice	ICC 8 Polar Ice	Polar Ice
			BJ100 Snow Field/ Ice Field		ICEARE Snowfield /Icefield
			BJ110 Tundra		
				ICC 1 Fast Ice	Fast Ice
				ICC 3 Growler Area	Growler Area
				ICC 4 Pancake Ice	Pancake Ice